DESCRIPTION

PHASE MEASUREMENT DEVICE, METHOD, PROGRAM, AND RECORDING MEDIUM

TECHNICAL FIELD

The present invention relates to a measurement of a phase of a distortion of a signal output from a non-linear circuit (circuit to be measured) upon a signal having at least two frequency components is fed to the non-linear circuit.

BACKGROUND ART

It has conventionally been a general practice to amplify a signal by feeding the signal to an amplifier. It is ideal that the amplifier is a linear circuit. However, it is difficult to manufacture an amplifier which is a completely linear circuit, and an amplifier is thus treated as a type of a non-linear circuit. Namely, if a signal is fed to an amplifier, distortion components in addition to an amplified signal is output.

A measurement of such distortion components has been practiced as described in Patent Document 1 (Japanese Laid-Open Patent Publication (Kokai) No. 2001-285211 (ABSTRACT)), for example.

However, a measurement of the phases of distortion components

output from an amplifier has not been practiced conventionally upon a signal having at least two frequency components being fed to the amplifier.

An object of the present invention is to measure the phases of distortions of a signal output from a circuit to be measured upon a signal having at least two frequency components is fed to the circuit to be measured.

DISCLOSURE OF THE INVENTION

According to an aspect of the present invention, a phase measurement device that measures an output from a circuit to be measured upon feeding an input signal having at least two input frequency components to the circuit to be measured, includes: a phase acquisition section that acquires phases of the input frequency components and a distortion component based upon a local frequency; a match time measurement unit that measures a match time at which the phases of the input frequency components match each other based upon an acquired result of the phase acquisition section; and a distortion component phase measurement unit that measures a phase of the distortion component at the match time based upon an acquired result of the phase acquisition section, wherein the distortion component includes at least either of a high frequency distortion component that has a frequency higher than the input frequency components, and a low frequency distortion component that has a frequency lower than the input frequency components, and the phase acquisition section acquires both or either of a highest frequency component and a lowest frequency component of the input frequency components, and a phase of the high

frequency distortion component or the low frequency distortion component.

According to the thus constructed invention, a phase measurement device that measures an output from a circuit to be measured upon feeding an input signal having at least two input frequency components to the circuit to be measured, is provided.

A phase acquisition section acquires phases of the input frequency components and a distortion component based upon a local frequency. A match time measurement unit measures a match time at which the phases of the input frequency components match each other based upon an acquired result of the phase acquisition section. A distortion component phase measurement unit measures a phase of the distortion component at the match time based upon an acquired result of the phase acquisition section. The distortion component includes at least either of a high frequency distortion component that has a frequency higher than the input frequency components, and a low frequency distortion component that has a frequency lower than the input frequency components. The phase acquisition section acquires both or either of a highest frequency component and a lowest frequency component of the input frequency components, and a phase of the high frequency distortion component or the low frequency distortion component.

According to the present invention, it is preferable that the phase acquisition section includes: an orthogonal transformation unit that orthogonally transforms the output from the circuit to be measured by means of the local frequency; and a phase acquisition unit that acquires the phases of the input frequency components and the distortion component in

outputs from the orthogonal transformation unit.

According to the present invention, it is preferable that the phase acquisition section acquires (1) the phases of the highest frequency component and the lowest frequency component of the input frequency components, and the phase of the low frequency distortion component, and (2) the phases of the highest frequency component and the lowest frequency component of the input frequency components, and the phase of the high frequency distortion component.

According to the present invention, it is preferable that the phase measurement device includes a local frequency setting unit that sets the local frequency, wherein the local frequency setting unit sets the local frequency both (3) to an average of the lowest frequency of the distortion components and the highest frequency of the input frequency components, and (4) to an average of the highest frequency of the distortion components and the lowest frequency of the input frequency components.

According to the present invention, it is preferable that the phase acquisition section acquires (5) the phase of the lowest frequency component of the input frequency components and the phase of the highest frequency component of the input frequency components, and (6) the phase of the lowest frequency component of the input frequency components and the phase of the low frequency distortion component, and (7) the phase of the highest frequency component of the input frequency components and the phase of the high frequency distortion component.

According to the present invention, it is preferable that the phase

measurement device includes a local frequency setting unit that sets the local frequency, wherein the local frequency setting unit sets the local frequency to an average of the lowest frequency and the highest frequency of the input frequency components, (8) to an average of the lowest frequency of the distortion component and the lowest frequency of the input frequency component, and (9) to an average of the highest frequency of the distortion component and the highest frequency of the input frequency component.

According to the present invention, it is preferable that the phase measurement device includes: a phase change quantity acquisition unit that acquires a phase change quantity of the highest frequency component or the lowest frequency component of the input frequency components which has changed due to a change of the components for which the phase acquisition section acquires the phases each time of the change; and a distortion component phase compensation unit that corrects the measurement result of the distortion component phase measurement unit based upon the phase change quantity.

According to the present invention, it is preferable that the phase acquisition section acquires (10) the phases of the highest frequency component and the lowest frequency component of the input frequency components, and (11) the lowest frequency component of the input frequency components and the phase of a neighboring low frequency distortion component which is a part of the low frequency distortion components, and acquires the phase of a low frequency distortion component whose phase has already been acquired and the phase of a low frequency distortion component whose frequency is lower than that of the low frequency distortion component until the acquisition of the phase of the distortion component at

the lowest frequency.

According to the present invention, it is preferable that the phase acquisition section acquires (12) the phases of the highest frequency component and the lowest frequency component of the input frequency components, and (13) the phases of the highest frequency component and the phase of a neighboring high frequency distortion component which is a part of the high frequency distortion components, and acquires the phase of a high frequency distortion component whose phase has already been acquired and the phase of a high frequency distortion component whose frequency is higher than that of the high frequency distortion component until the acquisition of the phase of the distortion component at the highest frequency.

According to the present invention, it is preferable that the phase measurement device includes a local frequency setting unit that sets the local frequency, wherein, upon the phase acquisition, the local frequency setting unit sets the local frequency to an average value of the maximum value and the minimum value of the frequency of the signals for which the phases are acquired.

According to the present invention, it is preferable that the phase measurement device includes: a phase change quantity acquisition unit that acquires a phase change quantity of a distortion component which has changed due to a change of the components for which the phase acquisition section acquires the phases each time of the change; and a distortion component phase compensation unit that corrects the measurement result of the distortion component phase measurement unit based upon the phase change quantity.

According to the present invention, it is preferable that the phase acquisition section includes a discrete Fourier transform unit that carries out discrete Fourier transform.

According to the present invention, it is preferable that the phase measurement device includes a display unit that displays a vector whose angle is the phase of the distortion component, and whose length is the amplitude of the distortion component.

According to the present invention, it is preferable that the display unit displays a vector whose length is a logarithm of the amplitude of the distortion component.

According to another aspect of the present invention, a phase measurement method of measuring an output from a circuit to be measured upon feeding an input signal having at least two input frequency components to the circuit to be measured, includes: a phase acquisition step of acquiring phases of the input frequency components and a distortion component based upon a local frequency; a match time measurement step of measuring a match time at which the phases of the input frequency components match each other based upon an acquired result of the phase acquisition step; and a distortion component phase measurement step of measuring a phase of the distortion component at the match time based upon an acquired result of the phase acquisition step, wherein the distortion component includes at least either of a high frequency distortion component that has a frequency higher than the input frequency components, and a low frequency distortion component that has a frequency lower than the input frequency components,

and the phase acquisition step acquires both or either of a highest frequency component and a lowest frequency component of the input frequency components, and a phase of the high frequency distortion component or the low frequency distortion component.

Another aspect of the present invention is a program of instructions for execution by the computer to perform a phase measurement process of a phase measurement device that measures an output from a circuit to be measured upon feeding an input signal having at least two input frequency components to the circuit to be measured, having a phase acquisition section that acquires phases of the input frequency components and a distortion component based upon a local frequency, the phase measurement process including: a match time measurement step of measuring a match time at which the phases of the input frequency components match each other based upon an acquired result of the phase acquisition section; and a distortion component phase measurement step of measuring a phase of the distortion component at the match time based upon an acquired result of the phase acquisition section, wherein the distortion component includes at least either of a high frequency distortion component that has a frequency higher than the input frequency components, and a low frequency distortion component that has a frequency lower than the input frequency components, and the phase acquisition section acquires both or either of a highest frequency component and a lowest frequency component of the input frequency components, and a phase of the high frequency distortion component or the low frequency distortion component.

Another aspect of the present invention is a computer-readable medium having a program of instructions for execution by the computer to

perform a phase measurement process of a phase measurement device that measures an output from a circuit to be measured upon feeding an input signal having at least two input frequency components to the circuit to be measured, having a phase acquisition section that acquires phases of the input frequency components and a distortion component based upon a local frequency, the phase measurement process including: a match time measurement step of measuring a match time at which the phases of the input frequency components match each other based upon an acquired result of the phase acquisition section; and a distortion component phase measurement step of measuring a phase of the distortion component at the match time based upon an acquired result of the phase acquisition section, wherein the distortion component includes at least either of a high frequency distortion component that has a frequency higher than the input frequency components, and a low frequency distortion component that has a frequency lower than the input frequency components, and the phase acquisition section acquires both or either of a highest frequency component and a lowest frequency component of the input frequency components, and a phase of the high frequency distortion component or the low frequency distortion component.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing a configuration of an amplifier measurement system according to a first embodiment of the present invention;

FIG. 2 is a diagram showing an operation of an amplifier 20, wherein FIG. 2(a) shows a frequency spectrum of an input signal fed to the amplifier

20, FIG. 2(b) shows a frequency spectrum of an output from the amplifier 20, and FIG. 2(c) shows a frequency spectrum of an output from the amplifier 20 in a case where $\omega 0$ (= ($\omega 10+\omega 20$)/2) is set to 0;

FIG. 3 shows a method to set the local frequency ωc according to the first embodiment of the present invention;

FIG. 4 is a block diagram showing a configuration of a phase acquisition section 40 according to the first embodiment of the present invention;

FIG. 5 is a diagram showing initial states (states at time t = 0) of complex vectors s1 and s2 according to the first embodiment of the present invention;

FIG. 6 is a chart showing relationships between the phase $\theta 1$ of the complex vector s1, the phase $\theta 2$ of the complex vector s2, and the time "t" according to the first embodiment of the present invention;

FIG. 7 is a chart showing relationships between the phase $\theta 1$ of the complex vector s1, the phase $\theta 2$ of the complex vector s2, and the phase $\theta 3$ of the complex vector s3 and time "t" according to the first embodiment of the present invention;

FIG. 8 is a chart showing a display form of a display section 70 according to the first embodiment of the present invention;

FIG. 9 is a chart showing a variation of the display form of the display section 70 according to the first embodiment of the present invention;

FIG. 10 is a block diagram showing a configuration of an amplifier measurement system according to a second embodiment of the present invention;

FIG. 11 is a block diagram showing a configuration of a match time/phase measurement section 50 according to the second embodiment of the present invention;

FIG. 12 shows a method to set the local frequency ωc according to the second embodiment of the present invention;

FIG. 13 is a block diagram showing a configuration of an amplifier measurement system according to a third embodiment of the present invention;

FIG. 14 is a block diagram showing a configuration of an amplifier measurement system according to a fourth embodiment of the present invention;

FIG. 15 shows a method to set the local frequency ωc; and

FIG. 16 shows a method to set the local frequency ωc.

BEST MODE FOR CARRYING OUT THE INVENTION

A description will now be given of embodiments of the present invention with reference to drawings.

First Embodiment

FIG. 1 is a block diagram showing a configuration of an amplifier measurement system according to a first embodiment of the present invention. The amplifier measurement system includes an input signal generation section 10, an amplifier (circuit to be measured) 20, an A/D converter 32, multipliers 34a and 34b, a local frequency setting section 36, a 90-degree phase shifter 38, a phase acquisition section 40, a match time/phase measurement section 50, a distortion component phase measurement section 60, and a display section 70.

The input signal generation section 10 generates an input signal

having two input frequency components $\omega 1$ and $\omega 2$. The input signal generation section 10 includes a first oscillator 12, a second oscillator 14, and an adder 16. The first oscillator 12 generates a signal of the frequency $\omega 10$. The second oscillator 14 generates a signal of the frequency $\omega 20$. The adder 16 adds the signal of the frequency $\omega 10$ and the signal of the frequency $\omega 20$ to each other, and outputs a result of the addition. An output from the adder 16 is an input signal. The input signal is fed to the amplifier 20.

The amplifier (circuit to be measured) 20 amplifies the fed input signal, and outputs a result of the amplification. A description will now be given of an operation of the amplifier 20 with reference to FIG. 2. The frequency spectrum of the input signal fed to the amplifier 20 includes the components of the frequency $\omega 10$ and the frequency $\omega 20$ as shown in FIG. 2(a). The amplifier 20 amplifies the input signal, and outputs the result of the amplification.

The frequency spectrum of the output from the amplifier 20 is as shown in FIG. 2(b). It is recognized that levels of the components of the frequency $\omega 10$ and the frequency $\omega 20$ increase. However, it is difficult to manufacture the amplifier 20 as a completely linear circuit, and the amplifier 20 is thus a non-linear circuit. As a result, there are output components (referred to as distortion components) of a frequency $\omega 30$ and a frequency $\omega 40$ in addition to the components of the frequencies $\omega 10$ and $\omega 20$.

On this occasion, if a frequency $\omega 0$ which is an average of the frequency $\omega 10$ and the frequency $\omega 20$ (= $(\omega 10+\omega 20)/2$) is set to 0, the

frequency spectrum of the output from the amplifier 20 is as shown in FIG. 2(c). Namely, $\omega 10$ is equal to $\omega 1$ (= $\omega 10-\omega 0$); $\omega 20$ is equal to $-\omega 1$ (= $\omega 20-\omega 0$); $\omega 30$ is equal to $3\omega 1$ (= $\omega 30-\omega 0$); and $\omega 40$ is equal to $-3\omega 1$ (= $\omega 40-\omega 0$). Since $\omega 1 > -\omega 1$, $\omega 1$ is the highest frequency component of input frequency components, and $-\omega 1$ is the lowest frequency component of the input frequency components.

The components of $3\omega 1$ and $-3\omega 1$ are referred to as third distortion components. Distortion components are not limited to the third ones, and there exist fifth distortion components ($5\omega 1$ and $-5\omega 1$), seventh distortion components ($7\omega 1$ and $-7\omega 1$), and distortion components of higher orders.

The phase measurement device 1 includes the A/D converter 32, the multipliers 34a and 34b, the local frequency setting section 36, the 90-degree phase shifter 38, the phase acquisition section 40, the match time/phase measurement section 50, the distortion component phase measurement section 60, and the display section 70.

The A/D converter 32 converts an output from the amplifier 20 into a digital signal. It should be noted that a frequency band to which the A/D converter 32 can adapt is BW.

The multiplier 34a multiplies an output from the A/D converter 32 by $\cos(\omega c \cdot t)$ output from the local frequency setting section 36, and outputs the product. The multiplier 34b multiplies the output from the A/D converter 32 by $-\sin(\omega c \cdot t)$ output from the 90-degree phase shifter 38, and outputs the product. The multipliers 34a and 34b carry out the orthogonal transformation by means of the frequency ωc.

The local frequency setting section 36 sets the local frequency ωc for the orthogonal transformation. FIG. 3 shows a method to set the local frequency ωc. In FIG. 3, it is assumed to measure the phase of signals within a range of frequency $-5\omega 1$ to $5\omega 1$. Thus, the highest frequency of the distortion components is $5\omega 1$, and the lowest frequency thereof is $-5\omega 1$. It should be noted that $\omega 1-(-\omega 1) = 2\omega 1 = \omega sep$. First, as shown in FIG. 3(a), the local frequency $\omega c = \omega 0-\omega sep$. If $\omega 0 = 0$, there holds $\omega c = (\omega 1+(\omega 1+(-5\omega 1))/2 = -2\omega 1$. Then, as shown in FIG. 3(b), the local frequency $\omega c = \omega 0+\omega sep$. If $\omega 0 = 0$, there holds $\omega c = ((-\omega 1)+5\omega 1))/2 = 2\omega 1$.

The 90-degree phase shifter 38 shifts the phase of an output from the local frequency setting section 36 by 90 degrees, and outputs the result of the shift.

The phase acquisition section 40 acquires the phases of the input frequency components ($\pm\omega 1$) and the distortion components (such as $+3\omega 1$) in the outputs from the multipliers 34a and 34b. FIG. 4 is a block diagram showing a configuration of the phase acquisition section 40. The phase acquisition section 40 includes a frequency shift section 44, a complex FFT (Fast Fourier Transform) section 46, and a phase determination section 48.

The frequency shift section 44 shifts the frequency of the outputs from the multipliers 34a and 34b by $\omega c-\omega 0$. For example, if the local frequency is $\omega c = \omega 0-\omega sep$ (refer to FIG. 3(a)), the frequency is shifted by $\omega c-\omega 0 = -\omega sep$, and if the local frequency $\omega c = \omega 0+\omega sep$ (refer to FIG. 3(b)), the frequency is shifted by $\omega c-\omega 0 = \omega sep$.

Moreover, with reference to FIG. 3(b), the input frequency component ($-\omega 1$) is treated as the frequency -1.5ωsep with ωc as an origin in the outputs from the multipliers 34a and 34b. The input frequency component ($+\omega 1$) is treated as the frequency -0.5ωsep with ωc as the origin in the outputs from the multipliers 34a and 34b. The distortion component ($+3\omega 1$) is treated as the frequency 0.5ωsep with ωc as the origin in the outputs from the multipliers 34a and 34b.

However, as described later, in the first embodiment (the same applied to other embodiments), the angular velocity of the input frequency component ($-\omega 1$) and the angular velocity of the input frequency component ($+\omega 1$) have the same magnitude (but have different in positive/negative signs), and the angular velocity of the distortion component ($+3\omega 1$) should be three times as large as that of the input frequency component ($+\omega 1$).

The origin is thus moved from ωc (= $\omega 0+\omega$sep) to $\omega 0$. As a result, the frequency of the outputs from the multipliers 34a and 34b are increased by ωsep by the frequency shift section 44. For example, the input frequency component ($-\omega 1$) will have the frequency -1.5ωsep + ωsep = -0.5ωsep. The input frequency component ($+\omega 1$) will have the frequency -0.5ωsep + ωsep = 0.5ωsep. The distortion component ($+3\omega 1$) will have the frequency 0.5ωsep + ωsep = 1.5ωsep.

Consequently, the angular velocity of the input frequency component ($-\omega 1$) and the angular velocity of the input frequency component ($+\omega 1$) have the same magnitude (but have different in positive/negative signs), and the angular velocity of the distortion component ($+3\omega 1$) is three times as large as that of the input frequency component ($+\omega 1$).

The complex FFT (Fast Fourier Transform) section 46 applies the complex fast Fourier transform to the outputs from the frequency shift section 44. As a result, complex vectors are acquired for the input frequency components ($\pm\omega 1$) and the distortion components (such as $+3\omega 1$). It should be noted that the complex FFT section 46 preferably carries out the discrete Fourier transform (DFT). Namely, the discrete Fourier transform (DFT) is applied to $\pm\omega 1$, $\pm 3\omega 1$, $\pm 5\omega 1$, ...

Since there can be selected an arbitrary number of points as calculation points of the discrete Fourier transform, it is possible to carry out the calculation by means of N which satisfies such a relationship as a desired frequency $f = fs/N \times k$ (fs: sampling frequency of the A/D converter 32, N: DFT calculation point number, and k: natural number) resulting in calculation with no influence of noises of nearby frequency components without changing the sampling frequency.

The phase determination section 48 determines the phases of the respective components based upon the complex vectors of the input frequency components ($\pm\omega 1$) and the distortion component (such as $+3\omega 1$). The phase can be calculated as $\tan^{-1}$ (imaginary part of complex vector/real part of complex vector). It is assumed that the phase of the input frequency component $+\omega 1$ is $\theta 1$, the phase of the input frequency component $-\omega 1$ is $\theta 2$, the phase of the distortion component $+3\omega 1$ is $\theta 3$, the phase of the distortion component $-3\omega 1$ is $\theta 4$, the phase of the distortion component $+5\omega 1$ is $\theta 5$, and the phase of the distortion component $-5\omega 1$ is $\theta 6$ (refer to FIG. 3). $\theta 1$, $\theta 2$, $\theta 3$, ... are functions of time. In the following section, a phase at time t is denoted as $\theta 1(t)$, for example.

It should be noted that $\theta 1$ is the phase of the highest frequency component of the input frequency components, and $\theta 2$ is the phase of the lowest frequency component of the input frequency components. Moreover, $\theta 3$ and $\theta 5$ are phases of high frequency distortion components whose frequency is higher than those of the input frequency components among the distortion components. Further, $\theta 4$ and $\theta 6$ are phases of low frequency distortion components whose frequency is lower than those of the input frequency components among the distortion components.

The phase determination section 48 determines $\theta 1$, $\theta 2$, $\theta 4$, and $\theta 6$ with reference to FIG. 3(a) (refer to (1) in FIG. 1). On this occasion, the local frequency ωc set by the local frequency setting section 36 is $\omega 0-\omega sep$.

In this case, it is necessary to measure across a bandwidth from $-5\omega 1$ to $+\omega 1$ with the local frequency ωc as the center. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be $BW > +\omega 1-(-5\omega 1) = 6\omega 1 = 3\omega sep$.

The phase determination section 48 then determines $\theta 1$, $\theta 2$, $\theta 3$, and $\theta 5$ with reference to FIG. 3(b) (refer to (2) in FIG. 1). On this occasion, the local frequency ωc set by the local frequency setting section 36 is $\omega 0+\omega sep$.

In this case, it is necessary to measure across a bandwidth $-\omega 1$ to $+5\omega 1$ with the local frequency ωc as the center. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be $BW > +5\omega$

$1-(-\omega 1) = 6\omega 1 = 3\omega sep$.

It should be noted that when $\theta 1$, $\theta 2$, $\theta 3$, $\theta 4$, $\theta 5$, and $\theta 6$ are measured at the same time, it is necessary to measure across a bandwidth from $-5\omega 1$ to $+5\omega 1$. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be $BW > +5\omega 1-(-5\omega 1) = 10\omega 1 = 5\omega sep$.

Consequently, if $\theta 1$, $\theta 2$, $\theta 4$, and $\theta 6$ are determined, and $\theta 1$, $\theta 2$, $\theta 3$, and $\theta 5$ are then determined as in the first embodiment, since it is necessary that $BW > 3\omega sep$, ωsep can be larger if BW is constant.

With reference again to FIG. 1, the match time/phase measurement section 50 measures a match time point Δt when the phase $\theta 1$ of the input frequency component $+\omega 1$ and the phase $\theta 2$ of the input frequency component $-\omega 1$ match each other for the first time, and the phase $\theta 1(\Delta t)$ ($= \theta 2(\Delta t)$) thereat based upon the acquisition result of the phase acquisition section 40.

A complex vector s1 of the input frequency component $+\omega 1$, and a complex vector s2 of the input frequency component $-\omega 1$ are represented by the following equations.

[EQU. 1]

$$s1 = A1 \times e^{j(\omega 1 \times t + \theta 1(0))}$$

$$s2 = A2 \times e^{j(-\omega 1 \times t + \theta 2(0))}$$

As the above equations clearly show, although the complex vectors s1 and s2 are different in length, they rotate at the same rotation speed in directions opposite to each other. In FIG. 5 are shown initial states (states at time t = 0) of the complex vectors s1 and s2. In FIG. 5, Im (imaginary part) is assigned to the vertical axis, and Re (real part) is assigned to the horizontal axis. An initial phase of the complex vector s1 is $\theta 1(0)$, and an initial phase of the complex vector s2 is $\theta 2(0)$. The phases of the complex vectors s1 and s2 match each other at the time point Δt for the first time. On this occasion, the phase $\theta 1(\Delta t)$ (= $\theta 2(\Delta t)$) is expressed by the following equation.

[EQU. 2]

$$\frac{-\theta 1(0)+\theta 2(0)}{2}+\theta 1(0)=\theta 1(\Delta t)$$

Since the complex vectors s1 and s2, whose phases become $\theta 1(\Delta t)$ at the time point Δt, rotate at the same rotational speed in the directions opposite to each other, the phases of the complex vectors s1 and s2 match each other at $\theta 1(\Delta t)+\pi$ when they rotate by 1/2 turn. The time point is $\Delta t+\pi/\omega 1$ on this occasion. The phases then match each other at $\theta 1(\Delta t)$ again. The time point is $\Delta t+2\pi/\omega 1$ on this occasion. In this way, the phases match each other at time point $\Delta t+n\cdot\pi/\omega 1$ (n = 0, 1, 2, ...) and the phases of the complex vectors s1 and s2 on this occasion are $\theta 1(\Delta t)$ (n = 0, 2, 4, ...) or $\theta 1(\Delta t)+\pi$ (n = 1, 3, 5, ...).

FIG. 6 shows relationships between the phase $\theta 1$ of the complex

vector s1, the phase $\theta 2$ of the complex vector s2, and the time "t" as a chart. It should be noted that $\theta 1(0) = 0$ for the sake of the illustration. As clearly shown in FIG. 6, the phases of the complex vectors s1 and s2 match each other at time point $\Delta t + n \cdot \pi/\omega 1$ ($n = 0, 1, 2, \ldots$) and the phases of the complex vectors s1 and s2 on this occasion are $\theta 1(\Delta t)$ ($n = 0, 2, 4, \ldots$) or $\theta 1(\Delta t)+\pi$ ($n = 1, 3, 5, \ldots$).

The distortion component phase measurement section 60 measures the phase $\theta 3(\Delta t)$ of the distortion component $+3\omega 1$ at the match time point Δt based upon the acquisition result of the phase acquisition section 40. The match time point Δt is acquired from the match time/phase measurement section 50. It should be noted that the phases $\theta 4$, $\theta 5$, and $\theta 6$ of other distortion components (such as $-3\omega 1$ and $\pm 5\omega 1$) are acquired similarly. A description will now be given of a method to measure the distortion phase with the phase $\theta 3$ (Δt) as an example. Other distortion phases are measured by means of the same method.

A complex vector s3 of the distortion component $+3\omega 1$ is represented by the following equation.

[EQU. 3]

$$s3 = A3 \times e^{j(3\omega 1 \times t + \theta 3(0))}$$

As the above equation clearly shows, the complex vector s3 rotates three turns while the complex vector s1 rotates one turn. If the complex

vector s1 rotates 1/2 turn, the complex vector s3 rotates 3/2 turn.

As a result, if the complex vector s1 rotates one turn from the phase $\theta 1(\Delta t)$, since the complex vector s3 rotates three turns, the phase of the complex vector s3 returns to the initial phase. Thus, if the complex vector s1 rotates "n" turns from the phase $\theta 1(\Delta t)$ (n = 1, 2, ...), the phase of the complex vector s3 returns to the phase $\theta 3(\Delta t)$ of the distortion component $+3\omega 1$ at the match time point Δt.

Moreover, if the complex vector s1 rotates 1/2 turn from the phase $\theta 1(\Delta t)$, since the complex vector s3 rotates 3/2 turns, the phase of the complex vector s3 advances by π. As a result, if the phase of the complex vector s1 becomes $\theta 1(\Delta t)+\pi$, the phase of the complex vector s3 becomes $\theta 3(\Delta t)+\pi$.

FIG. 7 shows relationships between the phase $\theta 1$ of the complex vector s1, the phase $\theta 2$ of the complex vector s2, and the phase $\theta 3$ of the complex vector s3 and time "t" as a chart. It should be noted that $\theta 1$ and $\theta 2$ are represented as short dashed long dashed lines, and $\theta 3$ is represented as solid lines in FIG. 7. As FIG. 7 clearly shows, the phase of the complex vector s3 is $\theta 3(\Delta t)$ at the time point $\Delta t+n \cdot \pi/\omega 1$ (n = 0, 2, 4, ...), and the phase of the complex vector s3 is $\theta 3(\Delta t)+\pi$ at the time point $\Delta t+n \cdot \pi/\omega 1$ (n = 1, 3, 5, ...).

In this way, the phases at which the complex vectors s1 and s2 match each other take constant values such as $\theta 1(\Delta t)$ and $\theta 1(\Delta t)+\pi$. At the same time, the phases of the complex vector s3 at which the complex vectors s1 and s2 match each other also take constant values such as $\theta 3(\Delta t)$ and θ

$3(\Delta t)+\pi$. Thus, it is significant to measure $\theta 1(\Delta t)$ as the value which represents the phase of the input frequency components $\pm\omega 1$, and $\theta 3(\Delta t)$ as the value which represents the phase of the distortion component $+3\omega 1$.

It should be noted that a relative phase of the complex vector s3 when the complex vectors s1 and s2 match each other with respect to the phases at which the complex vectors s1 and s2 match each other takes a constant value $\theta 3(\Delta t)-\theta 1(\Delta t)$.

Moreover, $\theta 4$, $\theta 5$, $\theta 6$, ..., takes constant values when the complex vectors s1 and s2 match each other. The relative phases of $\theta 4$, $\theta 5$, $\theta 6$, ..., thus take the constant values $\theta n(\Delta t)-\theta 1(\Delta t)$ ($n = 4, 5, 6, \ldots$) when the complex vectors s1 and s2 match each other.

The display section 70 displays the measurement result $\theta 1(\Delta t)$ by the match time/phase measurement section 50, and the measurement result $\theta 3(\Delta t)$ and the like by the distortion component phase measurement section 60.

FIG. 8 is a chart showing a display form of the display section 70. The display section 70 displays the input frequency component $+\omega 1$ and distortion components $\pm 3\omega 1$. It should be noted that vectors are displayed while the phases of the input frequency component and the distortion components are represented as the angles thereof, and amplitudes of the input frequency component and the distortion components are represented as the lengths thereof. It should be noted that the angle of the input frequency component $+\omega 1$ is 0 degree. Moreover, the distortion components $\pm 5\omega 1$ have small amplitudes, almost overlap the origin, and are

thus not shown.

FIG. 9 is a chart showing a variation of the display form of the display section 70. This variation is different from the example shown in FIG. 8 in that there are shown vectors whose lengths are logarithms of the amplitudes of the input frequency component and distortion components. Specifically, the amplitude scale is logarithmically compressed into dBc (while the carrier is considered as a low frequency component of the base signal) (a full range of the amplitude is compressed to 5dBc, and the origin is compressed to −80dBc, for example). As a result, the distortion components $\pm 5\omega 1$ can be displayed.

A description will now be given of an operation of the first embodiment.

First, the signal of the frequency $\omega 10$ output from the first oscillator 12, and the signal of the frequency $\omega 20$ output from the second oscillator 14 are added by the adder 16, and is fed as the input signal to the amplifier 20. The frequency spectrum of the input signal is as shown in FIG. 2(a).

The input signal is amplified by the amplifier 20. It should be noted that the amplifier 20 is a type of non-linear circuits, and thus outputs the distortion components (such as components at the frequency $\omega 30$ and the frequency $\omega 40$) in addition to the components at the frequency $\omega 10$ and the frequency $\omega 20$ (refer to FIG. 2(b)).

The output from the amplifier 20 is fed to the phase measurement device 1. The phase measurement device 1 serves to measure the output

from the amplifier 20.

First, the output from the amplifier 20 is orthogonally transformed by means of the local frequency ωc by the multipliers 34a and 34b. The local frequency setting section 36 sets the local frequency ωc to $\omega 0-\omega sep$. The local frequency setting section 36 then sets the local frequency ωc to $\omega 0+\omega sep$.

The outputs from the multiplier 34a and the multiplier 34b are fed to the complex FFT section 46. The complex FFT section 46 carries out the complex fast Fourier transform, and acquires the complex vectors for the input frequency components ($\pm\omega 1$) and the distortion components (such as $+3\omega 1$). The phase determination section 48 receives the complex vectors, and determines the phases of the respective components.

The match time/phase measurement section 50 receives the phase $\theta 1$ of the input frequency component $+\omega 1$ and the phase $\theta 2$ of the input frequency component $-\omega 1$ of the outputs from the phase determination section 48, and measures the match time point Δt at which $\theta 1$ and $\theta 2$ match each other for the first time, and the phase $\theta 1(\Delta t)$ (= $\theta 2(\Delta t)$) thereat (refer to FIG. 6).

The distortion component phase measurement section 60 receives the phase $\theta 3$ of the distortion component $+3\omega 1$ and the like of the outputs from the phase determination section 48, further receives the match time point Δt from the match time/phase measurement section 50, and measures the phase $\theta 3(\Delta t)$ of the distortion component $+3\omega 1$ and the like at the match time point Δt (refer to FIG. 7).

The display section 70 displays the measurement result $\theta 1(\Delta t)$ by the match time/phase measurement section 50, and the measurement result $\theta 3(\Delta t)$ and the like by the distortion component phase measurement section 60.

According to the first embodiment, the match time/phase measurement section 50 is caused to measure $\theta 1(\Delta t)$ significant as a value representing the phase of the input frequency component $\pm\omega 1$. Moreover, the distortion component phase measurement section 60 is caused to measure $\theta 3(\Delta t)$ and the like significant as values representing the phases of the distortion component $+3\omega 1$ and the like. Moreover, the display section 70 is caused to display $\theta 1(\Delta t)$ and $\theta 3(\Delta t)$ and the like. It is thus possible to measure and display the significant values as the values representing the phases of the distortion of the signal output from the amplifier 20 and the input frequency components.

Moreover, according to the first embodiment, since the frequency band to which the A/D converter 32 can adapt should be $BW > 3\omega sep$, ωsep can be larger if BW is constant compared with the case where $\theta 1$, $\theta 2$, $\theta 3$, $\theta 4$, $\theta 5$, and $\theta 6$ are measured at the same time ($BW > 5\omega sep$).

Second Embodiment

A second embodiment where the local frequency ωc is set in three steps ($\omega c = \omega 0$, $\omega c = \omega 0 - 1.5\omega sep$, $\omega c = \omega 0 + 1.5\omega sep$) is different from the first embodiment where the local frequency ωc is set in the two steps ($\omega c = \omega 0 - \omega sep$, $\omega c = \omega 0 + \omega sep$).

FIG. 10 is a block diagram showing a configuration of an amplifier measurement system according the second embodiment of the present invention. The amplifier measurement system includes the input signal generation section 10, the amplifier (circuit to be measured) 20, the A/D converter 32, the multipliers 34a and 34b, the local frequency setting section 36, the 90-degree phase shifter 38, the phase acquisition section 40, the match time/phase measurement section 50, the distortion component phase measurement section 60, and the display section 70. In the following section, similar components are denoted by the same numerals as of the first embodiment, and will be explained in no more details.

The input signal generation section 10, the amplifier (circuit to be measured) 20, the A/D converter 32, the multipliers 34a and 34b, and the 90-degree phase shifter 38 are the same as the first embodiment, and a description thereof, therefore is omitted.

The local frequency setting section 36 sets the local frequency ωc for the orthogonal transformation. FIG. 12 shows a method to set the local frequency ωc. In FIG. 12, it is assumed to measure the phase of signals within a range of frequency $-5\omega 1$ to $5\omega 1$. It should be noted that $\omega 1-(-\omega 1) = 2\omega 1 = \omega sep$. First, as shown in FIG. 12(a), the local frequency $\omega c = \omega 0$. Then, as shown in FIG. 12(b), the local frequency $\omega c = \omega 0-1.5\omega sep$. If $\omega 0 = 0$, there holds $\omega c = (-\omega 1+(-5\omega 1))/2 = -3\omega 1$. Finally, as shown in FIG. 12(c), the local frequency $\omega c = \omega 0+1.5\omega sep$. If $\omega 0 = 0$, there holds $\omega c = (\omega 1+5\omega 1)/2 = 3\omega 1$.

The phase acquisition section 40 acquires the phases of the input frequency components ($\pm\omega 1$) and the distortion components (such as $+3\omega 1$)

in the outputs from the multipliers 34a and 34b. A configuration of the phase acquisition section 40 is the same as that of the first embodiment (refer to FIG. 4).

The phase acquisition section 40 includes the frequency shift section 44, the complex FFT (Fast Fourier Transform) section 46, and the phase determination section 48. The frequency shift section 44 and the complex FFT (Fast Fourier Transform) section 46 are the same as those of the first embodiment, and will be explained in no more details.

The phase determination section 48 first refers to FIG. 12(a) to determine $\theta 1$ and $\theta 2$. On this occasion, the local frequency ωc set by the local frequency setting section 36 is $\omega 0$ (refer to (1) in FIG. 10).

In this case, it is necessary to measure across a bandwidth from $-\omega 1$ to $+\omega 1$ with the local frequency ωc as the center. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be $BW > +\omega 1-(-\omega 1) = 2\omega 1 = \omega sep$.

The phase determination section 48 then determines $\theta 2$, $\theta 4$, and $\theta 6$ with reference to FIG. 12(b) (refer to (2) in FIG. 10). On this occasion, the local frequency ωc set by the local frequency setting section 36 is $\omega 0-1.5\omega sep$.

In this case, it is necessary to measure across a bandwidth $-5\omega 1$ to $-\omega 1$ with the local frequency ωc as the center. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be $BW > -5\omega 1-(-\omega 1) = 4\omega 1 = 2\omega sep$.

The phase determination section 48 finally determines $\theta 1$, $\theta 3$, and $\theta 5$ with reference to FIG. 12(c) (refer to (3) in FIG. 10). On this occasion, the local frequency ωc set by the local frequency setting section 36 is $\omega 0+1.5\omega sep$.

In this case, it is necessary to measure across a bandwidth $+\omega 1$ to $+5\omega 1$ with the local frequency ωc as the center. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be $BW > +5\omega 1 - \omega 1 = 4\omega 1 = 2\omega sep$.

It should be noted that when $\theta 1$, $\theta 2$, $\theta 3$, $\theta 4$, $\theta 5$, and $\theta 6$ are measured at the same time, it is necessary to measure across a bandwidth from $-5\omega 1$ to $+5\omega 1$. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be $BW > +5\omega 1-(-5\omega 1) = 10\omega 1 = 5\omega sep$.

Consequently, if $\theta 1$ and $\theta 2$ are determined, $\theta 2$, $\theta 4$, and $\theta 6$ are then determined, and $\theta 1$, $\theta 3$, and $\theta 5$ are finally determined as in the second embodiment, since it is necessary that $BW > 2\omega sep$, ωsep can be larger if BW is constant.

With reference again to FIG. 1, the match time/phase measurement section 50 measures a match time point Δt when the phase $\theta 1$ of the input frequency component $+\omega 1$ and the phase $\theta 2$ of the input frequency component $-\omega 1$ match each other for the first time, and the phase $\theta 1(\Delta t)$ ($= \theta 2(\Delta t)$) thereat based upon the acquisition result of the phase acquisition section 40.

FIG. 11 is a block diagram showing a configuration of the match time/phase measurement section 50. The match time/phase measurement section 50 includes a match phase measurement section 52 and a match time measurement section 54.

The match phase measurement section 52 measures the match phase $\theta 1(\Delta t)$ when the phase $\theta 1$ of the input frequency component $+\omega 1$ and the phase $\theta 2$ of the input frequency component $-\omega 1$ match each other while the local frequency $\omega c = \omega 0$.

The match time measurement section 54 measures a time point $\Delta t2$ when $\theta 2$ matches $\theta 1(\Delta t)$ while the local frequency ωc is $\omega 0-1.5\omega sep$, and a time point $\Delta t3$ when $\theta 1$ matches $\theta 1(\Delta t)$ while the local frequency ωc is $\omega 0+1.5\omega sep$.

The distortion component phase measurement section 60 measures the phase $\theta 3(\Delta t3)$ of the distortion component $+3\omega 1$ and the like at the match time points $\Delta t2$ and $\Delta t3$ based upon the acquisition result by the phase acquisition section 40. The match time points $\Delta t2$ and $\Delta t3$ are acquired from the match time/phase measurement section 50. It should be noted that the phases $\theta 4$, $\theta 5$, and $\theta 6$ of other distortion components (such as $-3\omega 1$ and $\pm 5\omega 1$) are acquired similarly.

Namely, the distortion component phase measurement section 60 measures the phases $\theta 4$ and $\theta 6$ of the distortion components $-3\omega 1$ and $-5\omega 1$ at the time point $\Delta t2$ ($\theta 2$ matches $\theta 1$ at this time point) when $\theta 2$ matches $\theta 1(\Delta t)$ while the local frequency ωc is $\omega 0-1.5\omega sep$. Moreover, the distortion component phase measurement section 60 measures the

phases $\theta 3$ and $\theta 5$ of the distortion components $+3\omega 1$ and $+5\omega 1$ at the time point $\Delta t3$ ($\theta 2$ matches $\theta 1$ at this time point) when $\theta 1$ matches $\theta 1(\Delta t)$ while the local frequency ωc is $\omega 0+1.5\omega sep$.

The measurement of the distortion phase is the same as that of the first embodiment, and will be explained in no more details.

The display section 70 displays the measurement result $\theta 1(\Delta t)$ by the match time/phase measurement section 50, and the measurement result $\theta 3(\Delta t3)$ and the like by the distortion component phase measurement section 60. The display form of the display section 70 is the same as that of the first embodiment.

A description will now be given of an operation of the second embodiment.

First, the signal of the frequency $\omega 10$ output from the first oscillator 12, and the signal of the frequency $\omega 20$ output from the second oscillator 14 are added by the adder 16, and is fed as the input signal to the amplifier 20. The frequency spectrum of the input signal is as shown in FIG. 2(a).

The input signal is amplified by the amplifier 20. It should be noted that the amplifier 20 is a type of non-linear circuits, and thus outputs the distortion components (such as components with the frequency $\omega 30$ and the frequency $\omega 40$) in addition to the components with the frequency $\omega 10$ and the frequency $\omega 20$ (refer to FIG. 2(b)).

The output from the amplifier 20 is fed to the phase measurement

device 1. The phase measurement device 1 serves to measure the output from the amplifier 20.

First, the output from the amplifier 20 is orthogonally transformed by means of the local frequency ωc by the multipliers 34a and 34b. The local frequency setting section 36 sets the local frequency ωc to $\omega 0$. The local frequency setting section 36 then sets the local frequency ωc to $\omega 0-1.5\omega sep$. The local frequency setting section 36 finally sets the local frequency ωc to $\omega 0+1.5\omega sep$.

The outputs from the multiplier 34a and the multiplier 34b are fed to the complex FFT section 46. The complex FFT section 46 carries out the complex fast Fourier transform, and acquires the complex vectors for the input frequency components ($\pm\omega 1$) and the distortion components (such as $+3\omega 1$). The phase determination section 48 receives the complex vectors, and determines the phases of the respective components.

The match time/phase measurement section 50 receives the phase $\theta 1$ of the input frequency component $+\omega 1$ and the phase $\theta 2$ of the input frequency component $-\omega 1$ of the outputs from the phase determination section 48, and measures the match time point Δt at which $\theta 1$ and $\theta 2$ match each other for the first time, and the phase $\theta 1(\Delta t)$ (= $\theta 2(\Delta t)$) thereat.

The distortion component phase measurement section 60 receives the phase $\theta 3$ of the distortion component $+3\omega 1$ and the like of the outputs from the phase determination section 48, further receives the match time points $\Delta t2$ and $\Delta t3$ from the match time/phase measurement section 50, and

measures the phase $\theta 3(\Delta t3)$ of the distortion component $+3\omega 1$ and the like at the match time points $\Delta t2$ and $\Delta t3$.

The display section 70 displays the measurement result $\theta 1(\Delta t)$ by the match time/phase measurement section 50, and the measurement result $\theta 3(\Delta t3)$ and the like by the distortion component phase measurement section 60.

According to the second embodiment, there are obtained the same effects as in the first embodiment.

Moreover, according to the second embodiment, since the frequency band to which the A/D converter 32 can adapt should be $BW > 2\omega sep$, ωsep can be larger if BW is constant compared with the case where $\theta 1$, $\theta 2$, $\theta 3$, $\theta 4$, $\theta 5$, and $\theta 6$ are measured at the same time ($BW > 5\omega sep$).

Third Embodiment

A third embodiment is obtained by adding a common reference signal source 80, a phase change quantity acquisition section 90, and a distortion component phase compensation section 92 to the second embodiment in order to reproduce $\theta 1$ and $\theta 2$ when the local frequency setting section 36 changes the local frequency ωc from $\omega 0$ to $\omega 0-1.5\omega sep$ ($\omega 0+1.5\omega sep$).

FIG. 13 is a block diagram showing a configuration of an amplifier measurement system according the third embodiment of the present invention. The amplifier measurement system includes the input signal generation section 10, the amplifier (circuit to be measured) 20, the A/D converter 32, the multipliers 34a and 34b, the local frequency setting section

36, the 90-degree phase shifter 38, the phase acquisition section 40, the match time/phase measurement section 50, the distortion component phase measurement section 60, the display section 70, the common reference signal source 80, the phase change quantity acquisition section 90, and the distortion component phase compensation section 92. In the following section, similar components are denoted by the same numerals as of the second embodiment, and will be explained in no more details.

The input signal generation section 10, the amplifier (circuit to be measured) 20, the A/D converter 32, the multipliers 34a and 34b, the local frequency setting section 36, the 90-degree phase shifter 38, the phase acquisition section 40, the match time/phase measurement section 50, the distortion component phase measurement section 60, the display section 70 are the same as the second embodiment, and a description thereof, therefore is omitted. It should be noted that a description will later be given of the match time measurement section 54 of the match time/phase measurement section 50.

The common reference signal source 80 supplies a common reference signal common to the input signal generation section 10, and the A/D converter 32. The input signal generation section 10 determines generation timing of the input signals based upon the common reference signal. The A/D converter 32 determines generation timing for a sampling clock signal and a trigger signal based upon the common reference signal. It should be noted that the generation timing of the trigger signal is set to have the same period of an integer multiple of the one period of the input signal.

The phase change quantity acquisition section 90 acquires a phase

change quantity of the highest frequency component $\theta 1$ or the lowest frequency component $\theta 2$ of the input frequency components which have changed each time when the phase acquisition section 40 changes the components for which the phases are acquired.

Specifically, when the phase acquisition section 40 selects the components for which $\theta 1$ and $\theta 2$ are acquired, the phase change quantity acquisition section 90 acquires $\theta 1(0)$ and $\theta 2(0)$ from the phase acquisition section 40.

When the phase acquisition section 40 changes components to those for which $\theta 2$, $\theta 4$, and $\theta 6$ are acquired, the phase change quantity acquisition section 90 acquires $\theta 2(T1)$ from the phase acquisition section 40. It should be noted that T1 is such a value that $\theta 2(T1) = \theta 2(0)$ ($T1 = 2n\pi/\omega 1$, n is a positive integer). However, when the phase acquisition section 40 changes components for which phases are acquired, there is generated an error, and $\theta 2(T1) = \theta 2(0)$ thus does not hold. If the error is denoted as $\Delta\theta 2$, $\theta 2(T1) = \theta 2(0)+\Delta\theta 2$. Thus, $\Delta\theta 2$ is obtained as $\Delta\theta 2 = \theta 2(T1)-\theta 2(0)$, and is fed to the match time measurement section 54 and the distortion component phase compensation section 92.

Moreover, when the phase acquisition section 40 changes components to those for which $\theta 1$, $\theta 3$, and $\theta 5$ are acquired, the phase change quantity acquisition section 90 acquires $\theta 1(T2)$ from the phase acquisition section 40. It should be noted that T2 is such a value that $\theta 1(T2) = \theta 1(0)$ ($T2 = 2n\pi/\omega 1$, n is a positive integer). However, when the phase acquisition section 40 changes components for which phases are acquired, there is generated an error, and $\theta 1(T2) = \theta 1(0)$ thus does not hold. If the

error is denoted as $\Delta\theta 1$, $\theta 1(T2) = \theta 1(0)+\Delta\theta 1$. Thus, $\Delta\theta 1$ is obtained as $\Delta\theta 1 = \theta 1(T2)-\theta 1(0)$, and is fed to the match time measurement section 54 and the distortion component phase compensation section 92.

The match time measurement section 54 acquires the errors $\Delta\theta 1$ and $\Delta\theta 2$ from the phase change quantity acquisition section 90, and corrects $\theta 2$ while the local frequency ωc is $\omega 0-1.5\omega sep$, and $\theta 1$ while the local frequency ωc is $\omega 0+1.5\omega sep$. Namely, the errors $\Delta\theta 2$ and $\Delta\theta 1$ are subtracted. There is then measured a time point Δt when $\theta 2$ and $\theta 1$ from which the errors $\Delta\theta 2$ and $\Delta\theta 1$ are respectively subtracted match $\theta 1(\Delta t)$.

The distortion component phase compensation section 92 receives $\theta 4$ and $\theta 6$, and $\theta 3$ and $\theta 5$ from the phase determination section 48. The distortion component phase compensation section 92 then subtracts the error $\Delta\theta 2$ from $\theta 4$ and $\theta 6$, and subtracts the error $\Delta\theta 1$ from $\theta 3$ and $\theta 5$, and supplies the distortion component phase measurement section 60 with the results.

A description will now be given of an operation of the third embodiment.

First, the signal of the frequency $\omega 10$ output from the first oscillator 12, and the signal of the frequency $\omega 20$ output from the second oscillator 14 are added by the adder 16, and is fed as the input signal to the amplifier 20. The frequency spectrum of the input signal is as shown in FIG. 2(a).

The input signal is amplified by the amplifier 20. It should be noted

that the amplifier 20 is a type of non-linear circuits, and thus outputs the distortion components (such as components with the frequency $\omega 30$ and the frequency $\omega 40$) in addition to the components with the frequency $\omega 10$ and the frequency $\omega 20$ (refer to FIG. 2(b)).

The output from the amplifier 20 is fed to the phase measurement device 1. The phase measurement device 1 serves to measure the output from the amplifier 20.

First, the output from the amplifier 20 is orthogonally transformed by means of the local frequency ωc by the multipliers 34a and 34b. The local frequency setting section 36 sets the local frequency ωc to $\omega 0$. The local frequency setting section 36 then sets the local frequency ωc to $\omega 0-1.5\omega sep$. The local frequency setting section 36 finally sets the local frequency ωc to $\omega 0+1.5\omega sep$.

The outputs from the multiplier 34a and the multiplier 34b are fed to the complex FFT section 46. The complex FFT section 46 carries out the complex fast Fourier transform, and acquires the complex vectors for the input frequency components ($\pm\omega 1$) and the distortion components (such as $+3\omega 1$). The phase determination section 48 receives the complex vectors, and determines the phases of the respective components.

The phase change quantity acquisition section 90 acquires $\theta 1(0)$, $\theta 2(0)$, $\theta 2(T1)$, and $\theta 1(T2)$ from the phase determination section 48. The phase change quantity acquisition section 90 obtains $\Delta\theta 2$ while the error $\Delta\theta 2 = \theta 2(T1)-\theta 2(0)$, and $\Delta\theta 1$ while the error $\Delta\theta 1 = \theta 1(T2)-\theta 1(0)$. The errors $\Delta\theta 1$ and $\Delta\theta 2$ are fed to the match time measurement section

54.

The match time/phase measurement section 50 receives the phase $\theta 1$ of the input frequency component $+\omega 1$ and the phase $\theta 2$ of the input frequency component $-\omega 1$ of the outputs from the phase determination section 48, and measures the match time point Δt at which $\theta 1$ and $\theta 2$ match each other for the first time, and the phase $\theta 1(\Delta t)$ (= $\theta 2(\Delta t)$) thereat. It should be noted that the match time measurement section 54 corrects $\theta 2$ while the local frequency ωc is $\omega 0-1.5\omega sep$, and $\theta 1$ while the local frequency ωc is $\omega 0+1.5\omega sep$ by means of the errors $\Delta\theta 1$ and $\Delta\theta 2$ supplied from the phase change quantity acquisition section 90. Namely, the errors $\Delta\theta 2$ and $\Delta\theta 1$ are subtracted.

The distortion component phase compensation section 92 receives the phase $\theta 3$ of the distortion component $+3\omega 1$ and the like of the outputs from the phase determination section 48. The distortion component phase compensation section 92 is supplied with the errors $\Delta\theta 1$ and $\Delta\theta 2$ from the phase change quantity acquisition section 90. The distortion component phase compensation section 92 subtracts the error $\Delta\theta 2$ from $\theta 4$ and $\theta 6$, and subtracts the error $\Delta\theta 1$ from $\theta 3$ and $\theta 5$, and supplies the distortion component phase measurement section 60 with the results.

Moreover, the distortion component phase measurement section 60 receives the match time point Δt from the match time/phase measurement section 50, and measures the phase $\theta 3(\Delta t)$ of the distortion component $+3\omega 1$ at the match time point Δt and the like.

The display section 70 displays the measurement result $\theta 1(\Delta t)$ by

the match time/phase measurement section 50, and the measurement result $\theta 3(\Delta t)$ and the like by the distortion component phase measurement section 60.

According to the third embodiment, there are obtained the same effects as in the second embodiment.

Moreover, according to the third embodiment, by means of the common reference signal source 80, it is possible to reduce the phase change quantities (errors $\Delta\theta 1$ and $\Delta\theta 2$) of the highest frequency component $\theta 1$ and the lowest frequency component $\theta 2$ of the input frequency components which have changed each time when the phase acquisition section 40 changes the components for which the phases are acquired.

Further, by means of the phase change quantity acquisition section 90, it is possible to acquire the phase change quantities (errors $\Delta\theta 1$ and $\Delta\theta 2$) of the highest frequency component $\theta 1$ and the lowest frequency component $\theta 2$ of the input frequency components which have changed each time when the phase acquisition section 40 changes the components for which the phases are acquired. The acquired errors $\Delta\theta 1$ and $\Delta\theta 2$ are used by the match time measurement section 54 and the distortion component phase compensation section 92, and there are corrected $\theta 2$, $\theta 4$, and $\theta 6$ while the local frequency ωc is $\omega 0-1.5\omega sep$, and $\theta 1$, $\theta 3$, and $\theta 5$ while the local frequency ωc is $\omega 0+1.5\omega sep$. Thus, the errors $\Delta\theta 1$ and $\Delta\theta 2$ do not cause errors in the measurement of the phases of the distortion components.

Fourth Embodiment

The fourth embodiment is the third embodiment improved to measure seventh and higher distortion phases.

FIG. 14 is a block diagram showing a configuration of an amplifier measurement system according the fourth embodiment of the present invention. The amplifier measurement system includes the input signal generation section 10, the amplifier (circuit to be measured) 20, the A/D converter 32, the multipliers 34a and 34b, the local frequency setting section 36, the 90-degree phase shifter 38, the phase acquisition section 40, the match time/phase measurement section 50, the distortion component phase measurement section 60, the display section 70, the common reference signal source 80, the phase change quantity acquisition section 90, and the distortion component phase compensation section 92. In the following section, similar components are denoted by the same numerals as of the third embodiment, and will be explained in no more details.

The input signal generation section 10, the amplifier (circuit to be measured) 20, the A/D converter 32, and the multipliers 34a and 34b are the same as the third embodiment, and a description thereof, therefore is omitted.

The local frequency setting section 36 sets the local frequency ωc for the orthogonal transformation. FIGS. 15 and 16 show a method to set the local frequency ωc. It should be noted that $\omega 1-(-\omega 1) = 2\omega 1 = \omega sep$.

First, as shown in FIG. 15(a), the local frequency $\omega c = \omega 0$. Then, as shown in FIG. 15(b), the local frequency $\omega c = \omega 0-1.5\omega sep$. If $\omega 0 = 0$, there holds $\omega c = (-\omega 1+(-5\omega 1))/2 = -3\omega 1$. Then, as shown in FIG. 15(c),

the local frequency $\omega c = \omega 0-2.5\omega sep$. If $\omega 0 = 0$, there holds $\omega c = ((-3\omega 1)+(-7\omega 1))/2 = -5\omega 1$.

Then, as shown in FIG. 16(a), the local frequency $\omega c = \omega 0+1.5\omega sep$. If $\omega 0 = 0$, there holds $\omega c = (\omega 1+5\omega 1)/2 = -3\omega 1$. Finally, as shown in FIG. 16(b), the local frequency $\omega c = \omega 0+2.5\omega sep$. If $\omega 0 = 0$, there holds $\omega c = (3\omega 1+7\omega 1)/2 = 5\omega 1$.

It should be noted that the local frequency ωc is an average of the highest value and the lowest value of the frequency of signals for which the phase determination section 48 acquires the phases. For example, with reference to FIG. 16(b), $\theta 3$, $\theta 5$, and $\theta 7$ are acquired. On this occasion, the local frequency ωc set by the local frequency setting section 36 is an average $5\omega 1$ of the highest value $7\omega 1$ and the lowest value $3\omega 1$ of the frequency of the signals for which the phase determination section 48 acquires the phases.

The phase acquisition section 40 acquires the phases of the input frequency components ($\pm\omega 1$) and the distortion components (such as $+3\omega 1$) in the outputs from the multipliers 34a and 34b. A configuration of the phase acquisition section 40 is the same as that of the first embodiment (refer to FIG. 4). The phase acquisition section 40 includes the frequency shift section 44, the complex FFT (Fast Fourier Transform) section 46, and the phase determination section 48. The frequency shift section 44 and the complex FFT (Fast Fourier Transform) section 46 are the same as those of the first embodiment, and will be explained in no more details.

The phase determination section 48 first refers to FIG. 15(a) to

determine $\theta 1$ and $\theta 2$. On this occasion, the local frequency ωc set by the local frequency setting section 36 is $\omega 0$.

In this case, it is necessary to measure across a bandwidth from $-\omega 1$ to $+\omega 1$ with the local frequency ωc as the center. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be BW > $+\omega 1-(-\omega 1) = 2\omega 1 = \omega sep$.

The phase determination section 48 then determines $\theta 2$, $\theta 4$, and $\theta 6$ with reference to FIG. 15(b). On this occasion, the local frequency ωc set by the local frequency setting section 36 is $\omega 0-1.5\omega sep$.

In this case, it is necessary to measure across a bandwidth $-5\omega 1$ to $-\omega 1$ with the local frequency ωc as the center. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be BW > $-5\omega 1-(-\omega 1) = 4\omega 1 = 2\omega sep$.

The phase determination section 48 then determines $\theta 4$, $\theta 6$, and $\theta 8$ with reference to FIG. 15(c). On this occasion, the local frequency ωc set by the local frequency setting section 36 is $\omega 0-2.5\omega sep$.

In this case, it is necessary to measure across a bandwidth $-7\omega 1$ to $-3\omega 1$ with the local frequency ωc as the center. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be BW > $-7\omega 1-(-3\omega 1) = 4\omega 1 = 2\omega sep$.

Moreover, the phase determination section 48 determines $\theta 1$, $\theta 3$, and $\theta 5$ with reference to FIG. 16(a). On this occasion, the local frequency

ωc set by the local frequency setting section 36 is $\omega 0+1.5\omega sep$.

In this case, it is necessary to measure across a bandwidth $+\omega 1$ to $+5\omega 1$ with the local frequency ωc as the center. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be $BW > +5\omega 1-\omega 1 = 4\omega 1 = 2\omega sep$.

The phase determination section 48 finally determines $\theta 3$, $\theta 5$, and $\theta 7$ with reference to FIG. 16(b). On this occasion, the local frequency ωc set by the local frequency setting section 36 is $\omega 0+2.5\omega sep$.

In this case, it is necessary to measure across a bandwidth $+3\omega 1$ to $+7\omega 1$ with the local frequency ωc as the center. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be $BW > +7\omega 1-3\omega 1 = 4\omega 1 = 2\omega sep$.

It should be noted that when $\theta 1$, $\theta 2$, $\theta 3$, $\theta 4$, $\theta 5$, $\theta 6$, $\theta 7$, and $\theta 8$ are measured at the same time, it is necessary to measure across a bandwidth from $-7\omega 1$ to $+7\omega 1$. Therefore, the frequency bandwidth BW to which the A/D converter 32 can adapt is to be $BW > +7\omega 1-(-7\omega 1) = 14\omega 1 = 7\omega sep$.

Consequently, if $\theta 1$ and $\theta 2$ are determined, $\theta 2$, $\theta 4$, and $\theta 6$ are then determined, $\theta 4$, $\theta 6$, and $\theta 8$ are then determined, $\theta 1$, $\theta 3$, and $\theta 5$ are then determined, and $\theta 3$, $\theta 5$, and $\theta 7$ are finally determined as in the fourth embodiment, since it is necessary that $BW > 2\omega sep$, ωsep can be larger if BW is constant.

The 90-degree phase shifter 38, the phase acquisition section 40, the match time/phase measurement section 50, the distortion component phase measurement section 60, the display section 70, and the common reference signal source 80 are the same as the third embodiment, and a description thereof, therefore is omitted. It should be noted that a description will later be given of the match time measurement section 54 of the match time/phase measurement section 50.

The phase change quantity acquisition section 90 acquires a phase change quantity of the highest frequency component $\theta 1$ or the lowest frequency component $\theta 2$ of the input frequency components which have changed when the phase acquisition section 40 changes the components for which the phases are acquired to those for $\theta 2$, $\theta 4$, and $\theta 6$ or $\theta 1$, $\theta 3$, and $\theta 5$. This is the same as that of the third embodiment.

Moreover, the phase change quantity acquisition section 90 acquires a phase change quantity of the phase $\theta 4$ of the distortion component which has changed when the phase acquisition section 40 changes the components for which the phases are acquired to $\theta 4$, $\theta 6$, and $\theta 8$.

Specifically, when the phase acquisition section 40 changes components to those for which $\theta 2$, $\theta 4$, and $\theta 6$ are acquired, the phase change quantity acquisition section 90 acquires $\theta 4(T1)$ from the phase acquisition section 40.

Then, when the phase acquisition section 40 changes components to those for which $\theta 4$, $\theta 6$, and $\theta 8$ are acquired, the phase change quantity acquisition section 90 acquires $\theta 4(T3)$ from the phase acquisition section 40.

It should be noted that T3 is such a value that $\theta 4(T1) = \theta 4(T3)$. However, when the phase acquisition section 40 changes components for which phases are acquired, there is generated an error, and $\theta 4(T1) = \theta 4(T3)$ thus does not hold. If the error is denoted as $\Delta\theta 4$, $\theta 4(T3) = \theta 4(T1)+\Delta\theta 4$. Thus, $\Delta\theta 4$ is obtained as $\Delta\theta 4 = \theta 4(T3)-\theta 4(T1)$, and is fed to the match time measurement section 54 and the distortion component phase compensation section 92.

Moreover, the phase change quantity acquisition section 90 acquires a phase change quantity of the phase $\theta 3$ of the distortion component which has changed when the phase acquisition section 40 changes the components for which the phases are acquired to $\theta 3$, $\theta 5$, and $\theta 7$.

Specifically, when the phase acquisition section 40 changes components to those for which $\theta 1$, $\theta 3$, and $\theta 5$ are acquired, the phase change quantity acquisition section 90 acquires $\theta 3(T2)$ from the phase acquisition section 40.

Then, when the phase acquisition section 40 changes components to those for which $\theta 3$, $\theta 5$, and $\theta 7$ are acquired, the phase change quantity acquisition section 90 acquires $\theta 3(T4)$ from the phase acquisition section 40. It should be noted that T4 is such a value that $\theta 3(T4) = \theta 3(T2)$. However, when the phase acquisition section 40 changes components for which phases are acquired, there is generated an error, and $\theta 3(T4) = \theta 3(T2)$ thus does not hold. If the error is denoted as $\Delta\theta 3$, $\theta 3(T4) = \theta 3(T2)+\Delta\theta 3$. Thus, $\Delta\theta 3$ is obtained as $\Delta\theta 3 = \theta 3(T4)-\theta 3(T2)$, and is fed to the match time measurement section 54 and the distortion component phase compensation section 92.

The match time measurement section 54 acquires the errors $\Delta\theta 1$ and $\Delta\theta 2$ from the phase change quantity acquisition section 90, and corrects $\theta 2$ while the local frequency ωc is $\omega 0-1.5\omega sep$, and $\theta 1$ while the local frequency ωc is $\omega 0+1.5\omega sep$. Namely, the errors $\Delta\theta 2$ and $\Delta\theta 1$ are subtracted. There is then measured a time point Δt when $\theta 2$ and $\theta 1$ from which the errors $\Delta\theta 1$ and $\Delta\theta 2$ are respectively subtracted match $\theta 1(\Delta t)$.

Moreover, the match time measurement section 54 acquires the errors $\Delta\theta 3$ and $\Delta\theta 4$ from the phase change quantity acquisition section 90, and corrects $\theta 4$ while the local frequency ωc is $\omega 0-2.5\omega sep$, and $\theta 3$ while the local frequency ωc is $\omega 0+2.5\omega sep$. Namely, the errors $\Delta\theta 4$ and $\Delta\theta 3$ are subtracted. Moreover, the match time measurement section 54 acquires the phases $\Delta\theta 4$ and $\Delta\theta 3$ at the match time Δt from the distortion component phase measurement section 60.

The match time measurement section 54 then measures the time point Δt when the value obtained by subtracting the error $\Delta\theta 4$ from $\theta 4$ matches the phase $\theta 4$ at the match time Δt while the local frequency ωc is $0-2.5\omega sep$. The match time measurement section 54 then measures the time point Δt when the value obtained by subtracting the error $\Delta\theta 3$ from $\theta 3$ matches the phase $\theta 3$ at the match time Δt while the local frequency ωc is $\omega 0+2.5\omega sep$.

The distortion component phase compensation section 92 receives $\theta 4$ and $\theta 6$, and $\theta 3$ and $\theta 5$ from the phase determination section 48. Then, the distortion component phase compensation section 92 subtracts the

error $\Delta\theta 2$ from $\theta 4$ and $\theta 6$, and subtracts the error $\Delta\theta 1$ from $\theta 3$ and $\theta 5$, and supplies the distortion component phase measurement section 60 with the results.

Moreover, the distortion component phase compensation section 92 receives $\theta 4$, $\theta 6$, and $\theta 8$, and $\theta 3$, $\theta 5$, and $\theta 7$ from the phase determination section 48. The distortion component phase compensation section 92 then subtracts the error $\Delta\theta 4$ from $\theta 4$, $\theta 6$, and $\theta 8$, and subtracts the error $\Delta\theta 3$ from $\theta 3$, $\theta 5$, and $\theta 7$, and supplies the distortion component phase measurement section 60 with the results.

The distortion component phase measurement section 60 measures the phases $\theta 4$, $\theta 6$, and $\theta 8$, and $\theta 3$, $\theta 5$, and $\theta 7$ of the distortion components at the match time point Δt based upon the acquisition result of the phase acquisition section 40.

A description will now be given of an operation of the fourth embodiment.

First, the signal of the frequency $\omega 10$ output from the first oscillator 12, and the signal of the frequency $\omega 20$ output from the second oscillator 14 are added by the adder 16, and is fed as the input signal to the amplifier 20. The frequency spectrum of the input signal is as shown in FIG. 2(a).

The input signal is amplified by the amplifier 20. It should be noted that the amplifier 20 is a type of non-linear circuits, and thus outputs the distortion components (such as components with the frequency $\omega 30$ and the frequency $\omega 40$) in addition to the components with the frequency $\omega 10$ and

the frequency $\omega 20$ (refer to FIG. 2(b)).

The output from the amplifier 20 is fed to the phase measurement device 1. The phase measurement device 1 serves to measure the output from the amplifier 20.

First, the output from the amplifier 20 is orthogonally transformed by means of the local frequency ωc by the multipliers 34a and 34b. The local frequency setting section 36 sets the local frequency ωc to $\omega 0$. The local frequency setting section 36 then sets the local frequency ωc to $\omega 0-1.5\omega sep$, and then to $\omega 0-2.5\omega sep$. The local frequency setting section 36 then sets the local frequency ωc to $\omega 0+1.5\omega sep$, and finally to $\omega 0+2.5 \omega sep$.

The outputs from the multiplier 34a and the multiplier 34b are fed to the complex FFT section 46. The complex FFT section 46 carries out the complex fast Fourier transform, and acquires the complex vectors for the input frequency components ($\pm\omega 1$) and the distortion components (such as $+3\omega 1$). The phase determination section 48 receives the complex vectors, and determines the phases of the respective components.

The phase change quantity acquisition section 90 acquires $\theta 1(0)$, $\theta 2(0)$, $\theta 2(T1)$, and $\theta 1(T2)$ from the phase determination section 48. The phase change quantity acquisition section 90 obtains $\Delta\theta 2$ while the error $\Delta\theta 2 = \theta 2(T1)-\theta 2(0)$, and $\Delta\theta 1$ while the error $\Delta\theta 1 = \theta 1(T2)-\theta 1(0)$. The errors $\Delta\theta 1$ and $\Delta\theta 2$ are fed to the match time measurement section 54.

Alternatively, the phase change quantity acquisition section 90 acquires the errors $\Delta\theta 3$ and $\Delta\theta 4$, and supplies the match time measurement section 54 with them.

The match time/phase measurement section 50 receives the phase $\theta 1$ of the input frequency component $+\omega 1$ and the phase $\theta 2$ of the input frequency component $-\omega 1$ of the outputs from the phase determination section 48, and measures the match time point Δt at which $\theta 1$ and $\theta 2$ match each other for the first time, and the phase $\theta 1(\Delta t)$ ($= \theta 2(\Delta t)$) thereat.

It should be noted that the match time measurement section 54 corrects $\theta 2$ while the local frequency ωc is $\omega 0-1.5\omega sep$, and $\theta 1$ while the local frequency ωc is $\omega 0+1.5\omega sep$ by means of the errors $\Delta\theta 1$ and $\Delta\theta 2$ supplied from the phase change quantity acquisition section 90. Namely, the errors $\Delta\theta 2$ and $\Delta\theta 1$ are subtracted.

The match time measurement section 54 then measures the time point Δt when the value obtained by subtracting the error $\Delta\theta 4$ from $\theta 4$ matches the phase $\theta 4$ at the match time Δt while the local frequency ωc is $0-2.5\omega sep$. The match time measurement section 54 then measures the time point Δt when the value obtained by subtracting the error $\Delta\theta 3$ from $\theta 3$ matches the phase $\theta 3$ at the match time Δt while the local frequency ωc is $0+2.5\omega sep$.

The distortion component phase compensation section 92 receives the phase $\theta 3$ of the distortion component $+3\omega 1$ and the like of the outputs from the phase determination section 48. The distortion component phase

compensation section 92 is supplied with the errors $\Delta\theta 1$ and $\Delta\theta 2$ from the phase change quantity acquisition section 90. The distortion component phase compensation section 92 subtracts the error $\Delta\theta 2$ from $\theta 4$ and $\theta 6$ (when $\theta 2$, $\theta 4$, and $\theta 6$ are measured), and subtracts the error $\Delta\theta 1$ from $\theta 3$ and $\theta 5$ (when $\theta 1$, $\theta 3$, and $\theta 5$ are measured), and supplies the distortion component phase measurement section 60 with the results. Alternatively, the distortion component phase compensation section 92 subtracts the error $\Delta\theta 4$ from $\theta 4$, $\theta 6$, and $\theta 8$ (when $\theta 4$, $\theta 6$, and $\theta 8$ are measured), and subtracts the error $\Delta\theta 3$ from $\theta 3$, $\theta 5$, and $\theta 7$ (when $\theta 3$, $\theta 5$, and $\theta 7$ are measured), and supplies the distortion component phase measurement section 60 with the results.

Moreover, the distortion component phase measurement section 60 receives the match time point Δt from the match time/phase measurement section 50, and measures the phase $\theta 3(\Delta t)$ of the distortion component $+3\omega 1$ at the match time point Δt and the like.

The display section 70 displays the measurement result $\theta 1(\Delta t)$ by the match time/phase measurement section 50, and the measurement result $\theta 3(\Delta t)$ and the like by the distortion component phase measurement section 60.

According to the fourth embodiment, there are obtained the same effects as in the third embodiment.

Moreover, according to the fourth embodiment, it is possible to measure the phases of the seventh distortions ($\theta 7$ and $\theta 8$). It should be noted that the phases of seventh and higher (such as ninth and eleventh)

distortions can be similarly measured according to the fourth embodiment. A description will now be given of measurement of the phases of ninth distortion components and eleventh distortion components as an example.

It is assumed that the phase of a high frequency distortion component of the ninth distortion is denoted as $\theta 9$, and the phase of a high frequency distortion component of the eleventh distortion is denoted as $\theta 11$. The phase $\theta 7$ of the high frequency distortion component of the seventh distortion is determined based upon the measurement result of $\theta 3$, $\theta 5$, and $\theta 7$ (refer to FIG. 16(b)). Similarly, the phase $\theta 9$ is determined based upon the measurement result of $\theta 5$, $\theta 7$, and $\theta 9$, and the phase $\theta 11$ is determined based upon the measurement result of $\theta 7$, $\theta 9$, and $\theta 11$.

Moreover, it is assumed that the phase of a low frequency distortion component of the ninth distortion is denoted as $\theta 10$, and the phase of a low frequency distortion component of the eleventh distortion is denoted as $\theta 12$. The phase $\theta 8$ of the low frequency distortion component of the seventh distortion is determined based upon the measurement result of $\theta 4$, $\theta 6$, and $\theta 8$ (refer to FIG. 15(c)). Similarly, the phase $\theta 10$ is determined based upon the measurement result of $\theta 6$, $\theta 8$, and $\theta 10$, and the phase $\theta 12$ is determined based upon the measurement result of $\theta 8$, $\theta 10$, and $\theta 12$.

Moreover, the above-described embodiment may be realized in the following manner. A computer is provided with a CPU, a hard disk, and a media (such as a floppy disk (registered trade mark) and a CD-ROM) reader, and the media reader is caused to read a medium recording a program realizing the above-described respective components (such as the match

time/phase measurement section 50 and the distortion component phase measurement section 60), thereby installing the program on the hard disk. This method may also realize the above-described embodiments.